Life After Airliners

Part VI

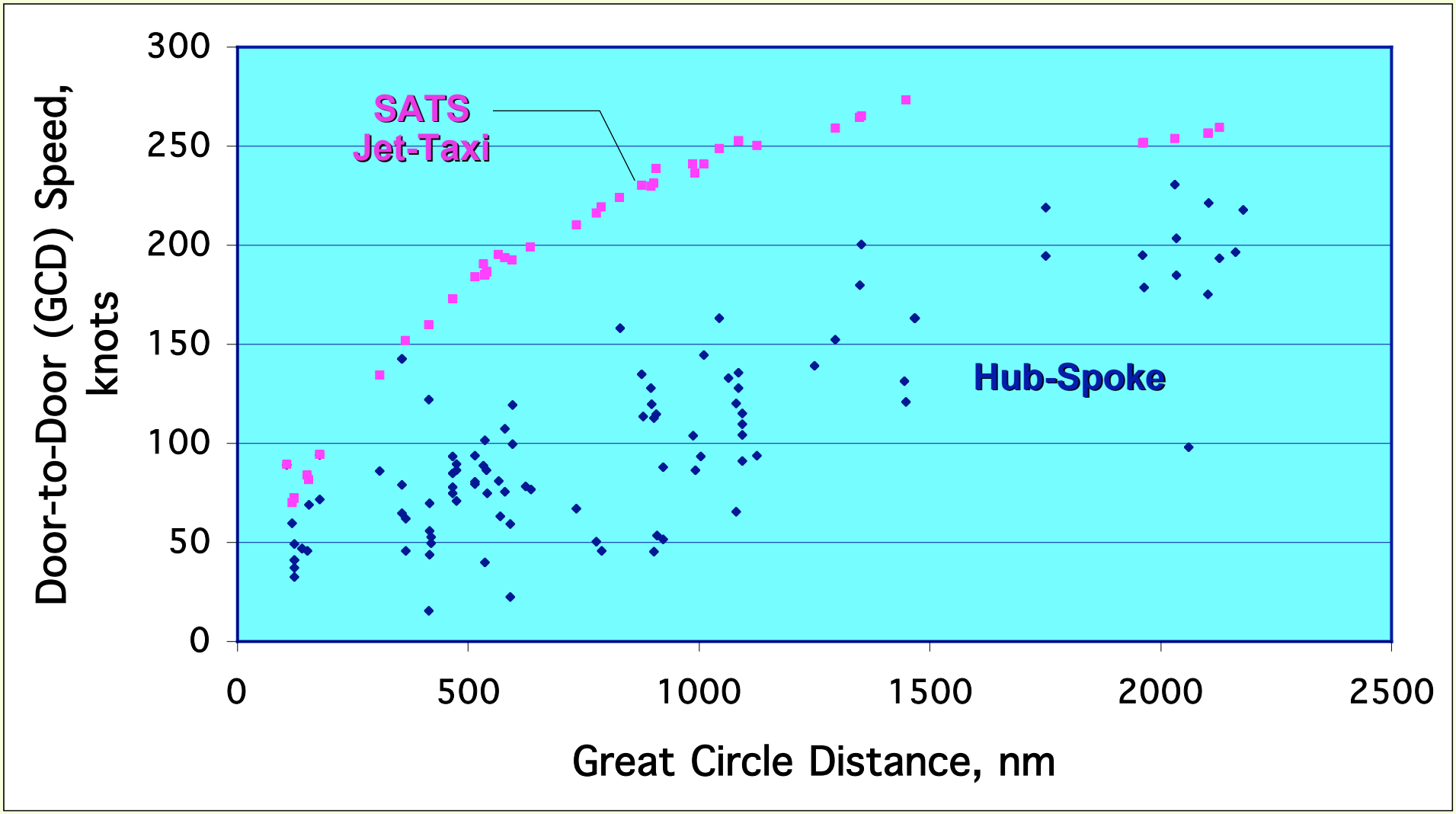
EAA AirVenture 2003
Oshkosh, Wisconsin
August 3, 2003

Outline

- Centennial Context for Transportation System Innovation
- SATS, The Vision
- SATS, The Project
- NASA Personal Air Vehicle Research Planning
- Modern Network Theory Implications to Air Transportation Systems
- A Notional Technology Roadmap

It is extremely unlikely
that the world will ever take such a step forward
in every means of locomotion as has been taken ...
between the year 1830 and the present date."
-- The Rudder magazine, October 1899

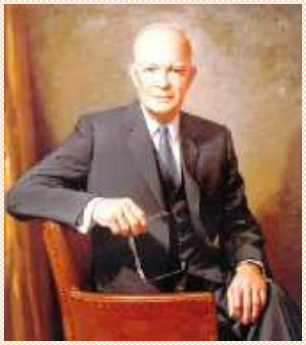
Comparison of Actual and Theoretical Speed of Doorstep-to-Destination Travel



(Bi) Centennial Context for Disruptive Innovation in Transportation Systems

Jefferson sends Lewis and Clark to discover a path for commerce

The Transcontinental Railroad connects east and west



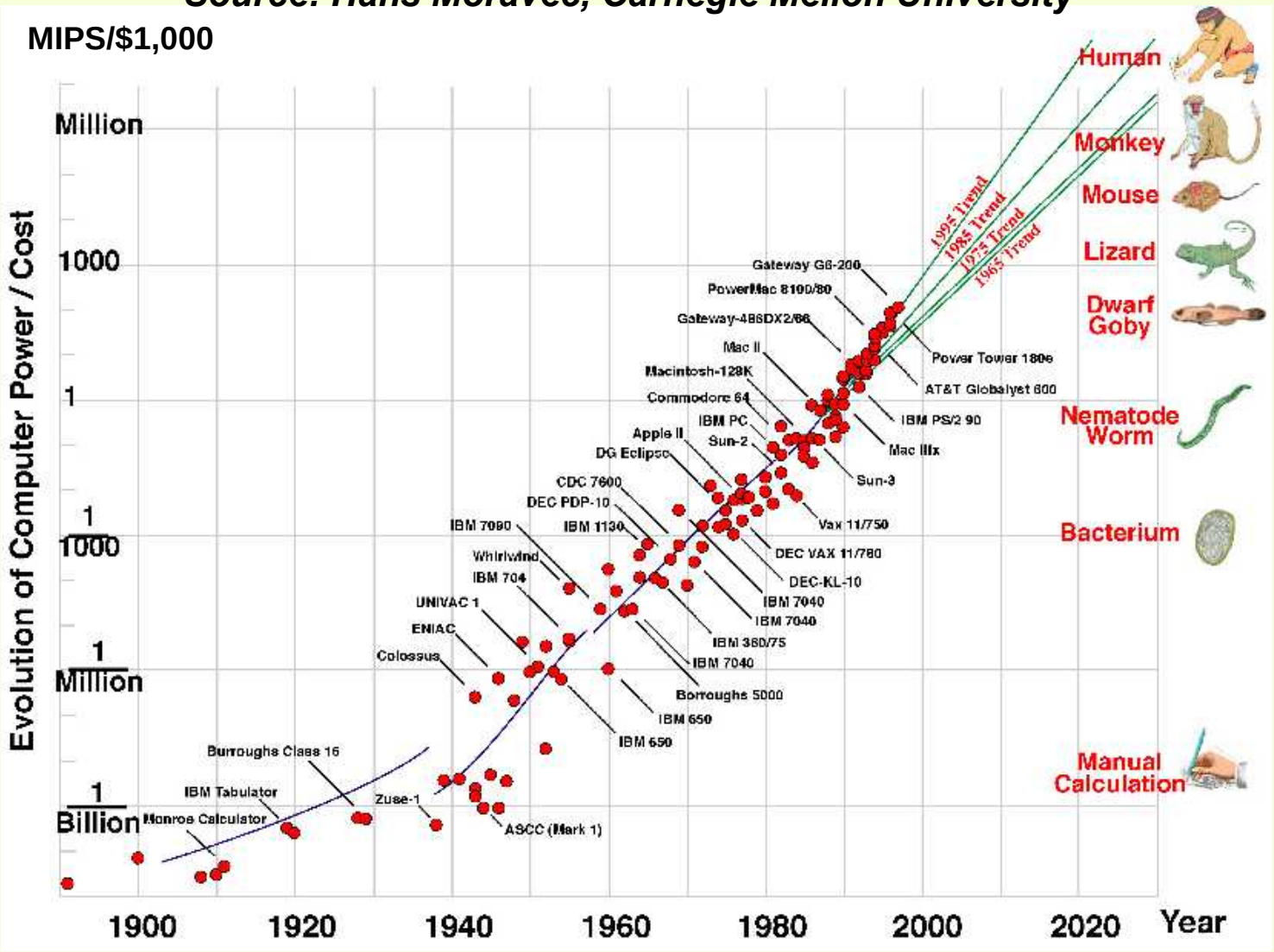
The Interstate Highway system connects the nation's cities

Technological Underpinnings for Mobility Alternatives

1. **Moore's Law on microprocessor cost/performance**
2. **Gilder's Law on bandwidth performance**
3. **Metcalf's Law on network performance**
4. **The unwritten law of abundance**
5. **The unwritten rule of gridlock**
6. **Kurzweil's Law of Accelerating Returns**
7. **The Golden Rule of the information age**

Evolution of Computer Power/Cost (Moore's Law)

Source: Hans Moravec, Carnegie Mellon University



Impact: Processing power that can mimic the human brain

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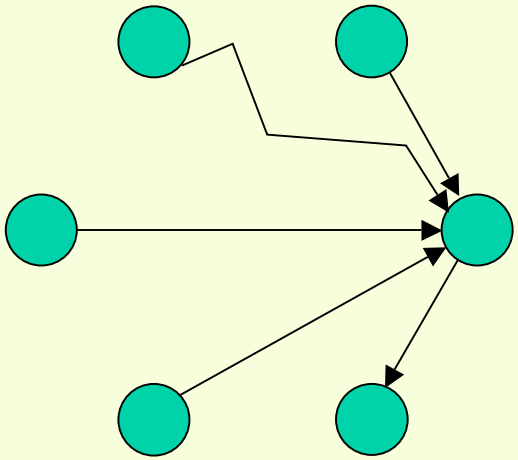
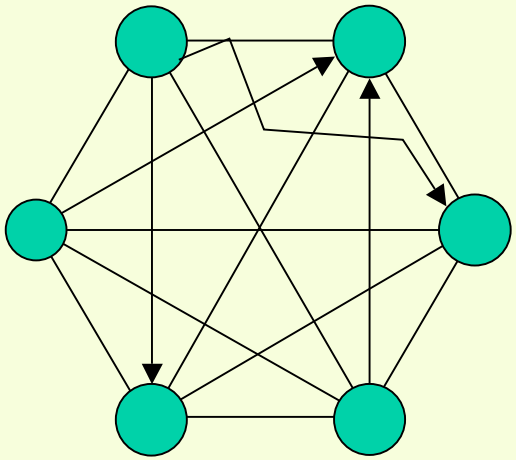
Value of Networks ≈ (# of Nodes)^2 (Metcalf's Law)

A. Hub-and-Spoke
Directed, Scheduled, Aggregated



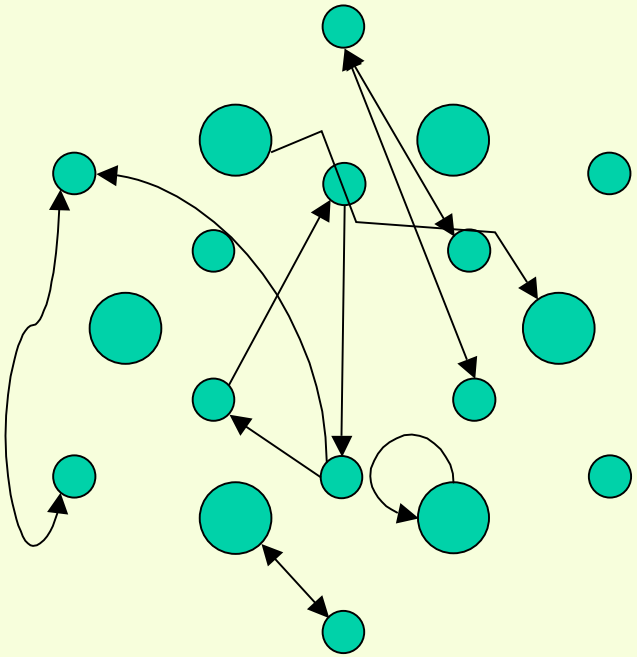
Nodes (n) = 6
Links (k) = n-1 = 5
Tier 1,2 Carriers

B. Point-to-Point
Directed, Scheduled, Aggregated



Nodes (n) = 6
Links (k) = n(n-1)/2 = 15
Tier 2,3 Carriers

C. Distributed
Undirected, On-Demand
Dis-Aggregated



Nodes (n) = 18
Links (k) = n(n-1)/2 = 153
(Three times the nodes = 10X links)
Tier 4 Carriers, UAVs, RIAs, PAVs

Technological Underpinnings for Mobility Alternatives

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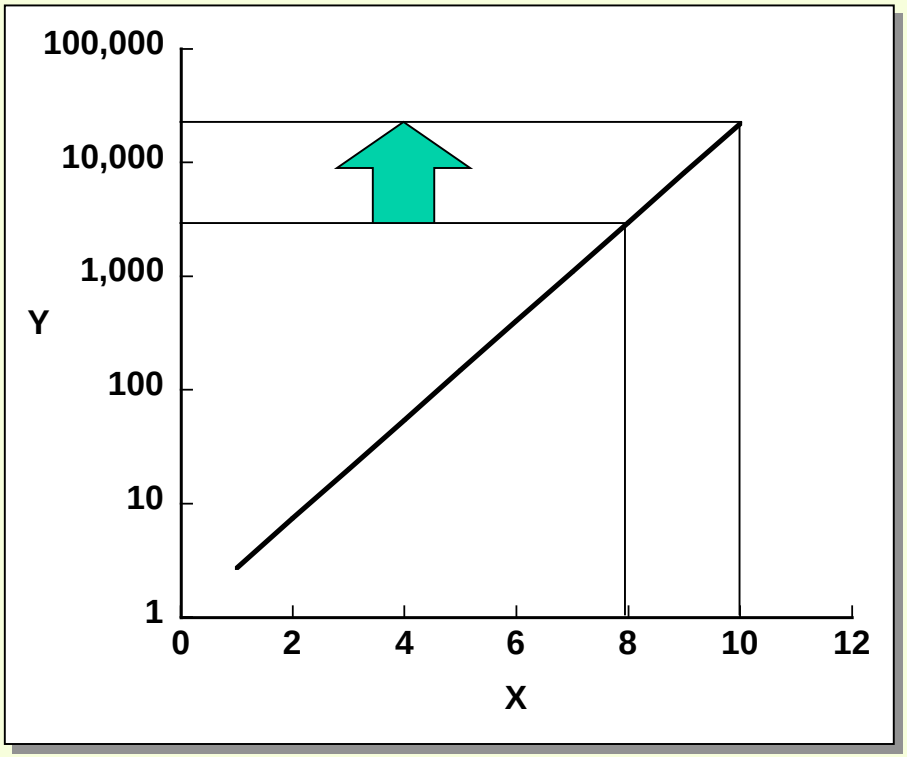
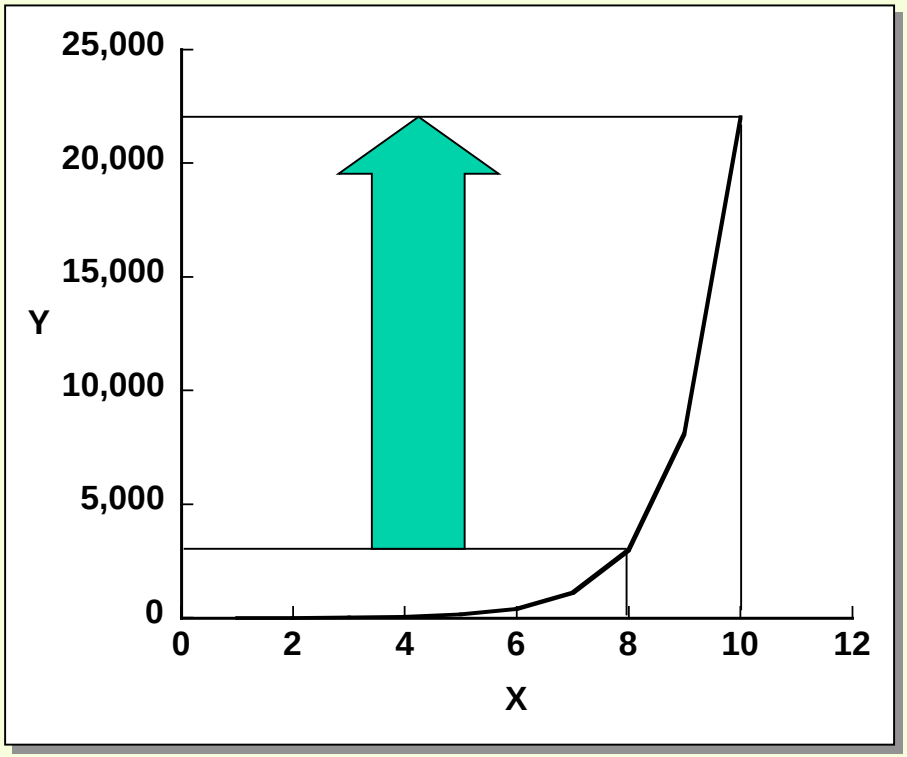
Accelerating Trends in Supporting Technologies
(Kurzweil's Law)

Linear Processes



Exponential Processes



Real Estate Value

New Mexico and California **… I hold that they are not worth a dollar!**

Daniel Webster: Senate Speech, 1848

Predicting Manned Flight

Man Will Not Fly for Fifty Years!

Wilbur Wright to his brother Orville, 1901

Predicting the Future of Air Travel

"…It [Aeroplane] is not likely that it will ever carry more than 5 or 7 passengers"

Waldemar Kaempfert
(Managing editor of *Scientific American*) June, 1913

Real Estate

Alaskian Acquisition

"…Alaska, is … worth nothing … Of what possible commercial importance can this territory be to us"

Orange Ferriss: House of Rep. Debate, 1868

Technological Underpinnings for Mobility Alternatives

1. **Moore's Law on microprocessor cost/performance**
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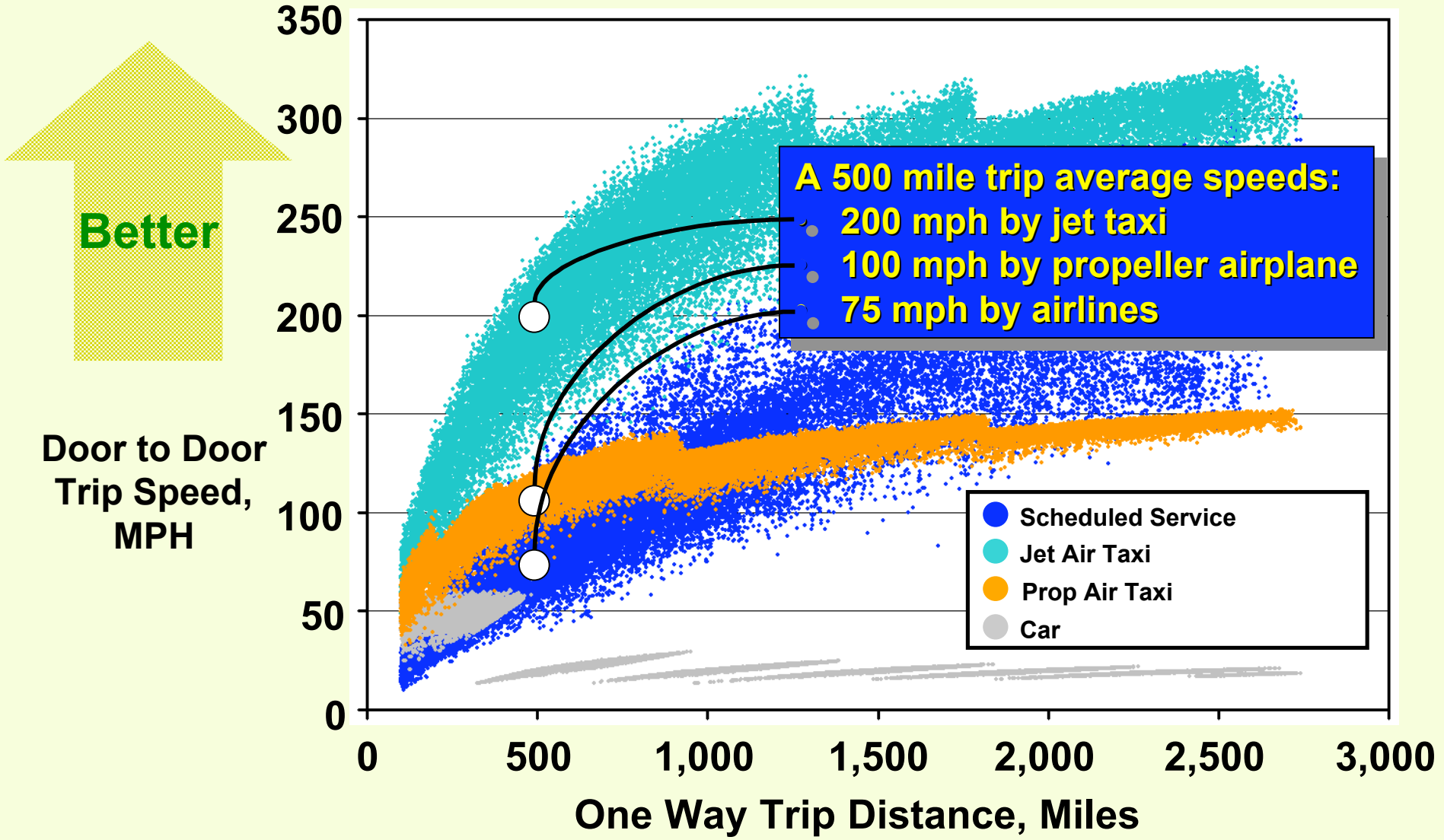
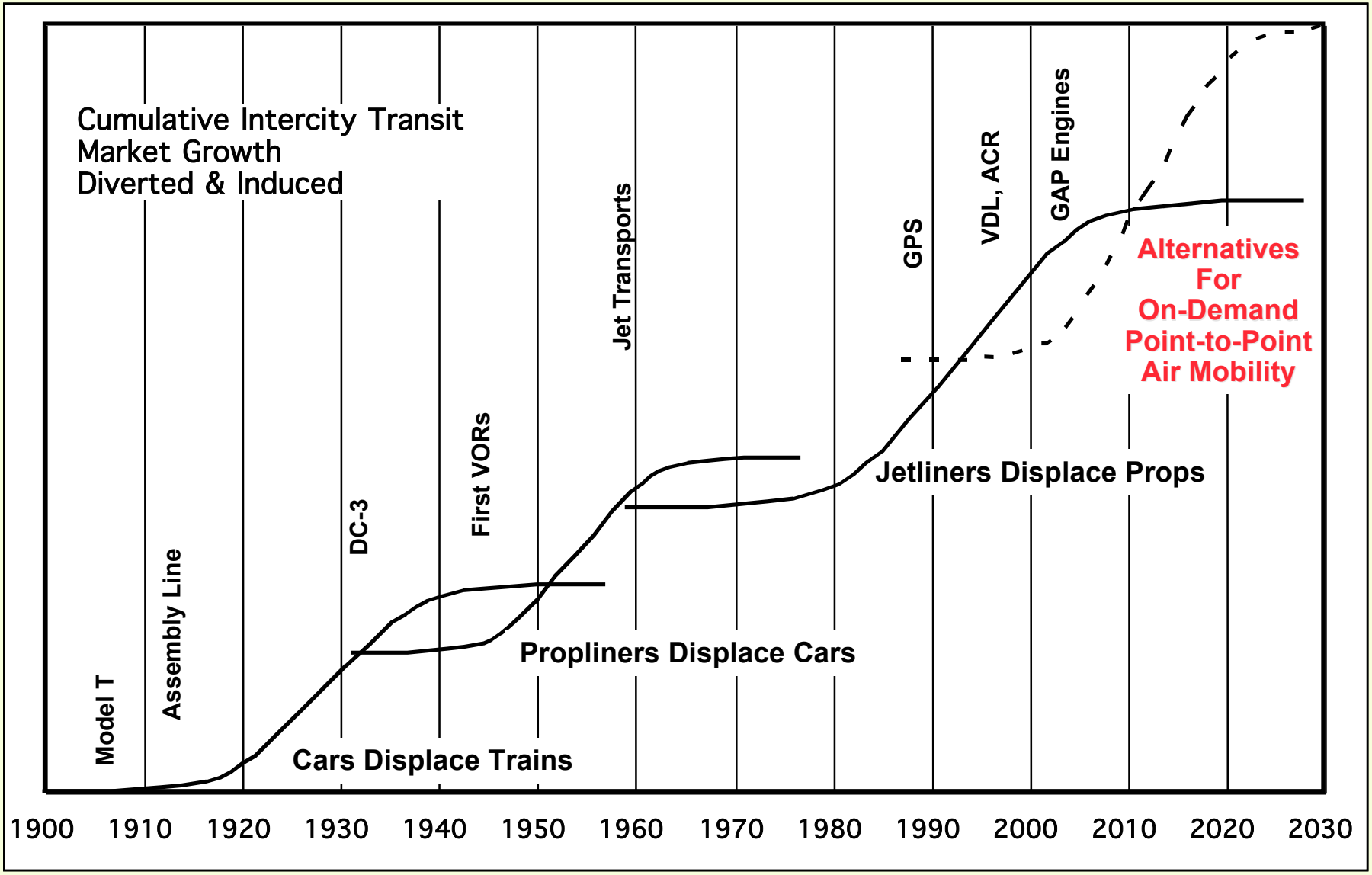
If Time is Gold

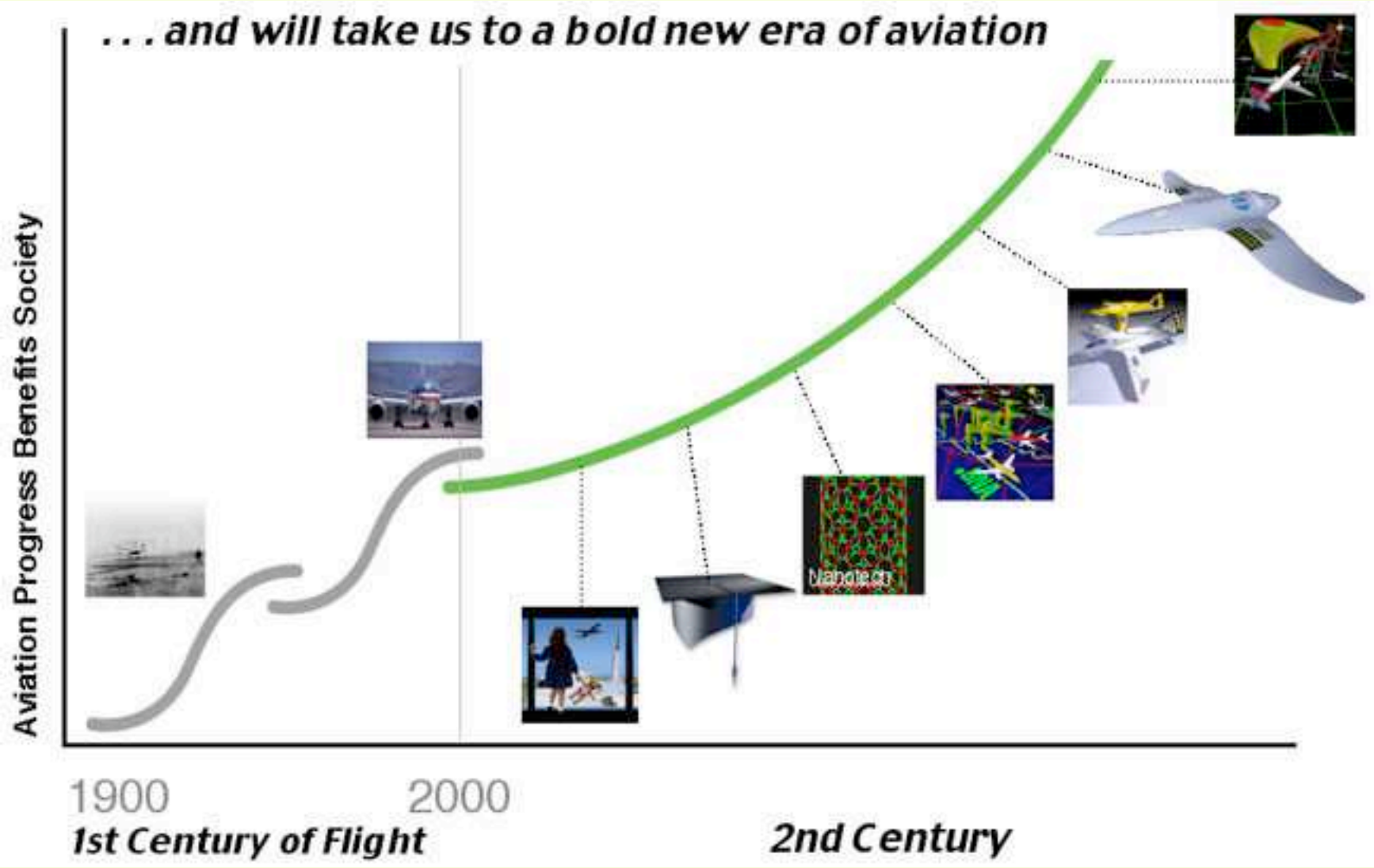
Then Door-to-Door Speed is the Coin of the Realm



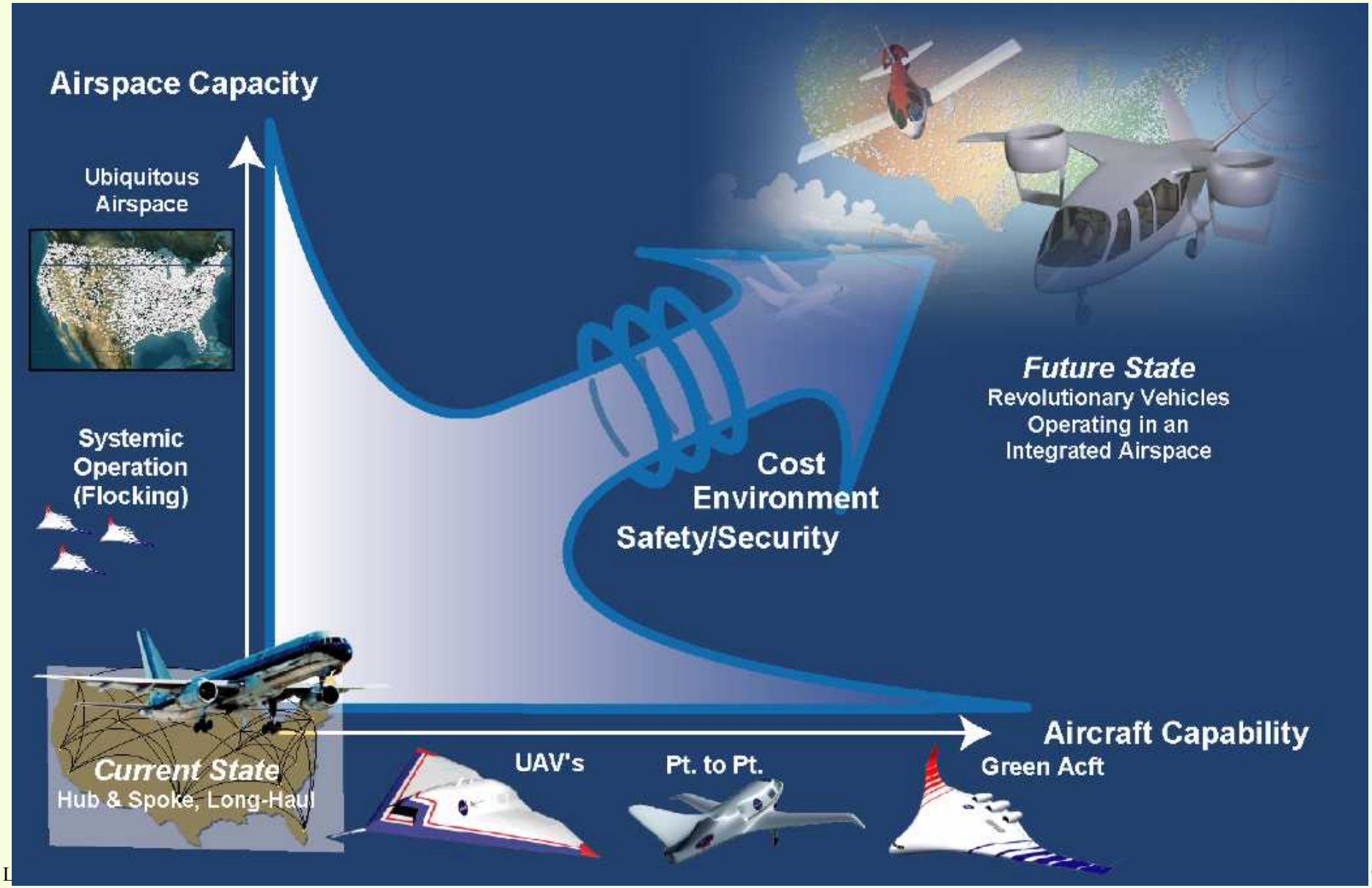
Notional Life Cycles in Transportation



Aviation's Future is Driven By Technology (NASA Blueprint for 21st Century Aeronautics)

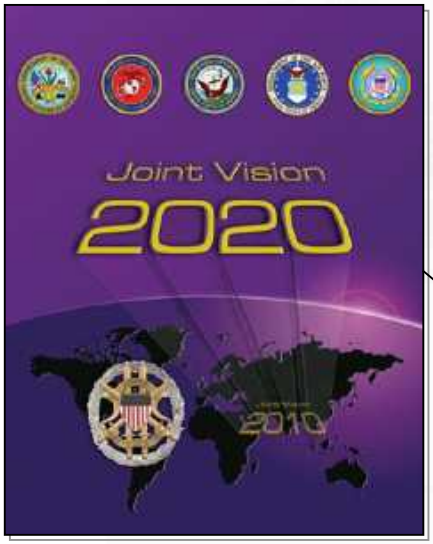


Integrated Advancements in Airspace and Vehicles



Leadership Strategies

DoD Joint Vision 2020

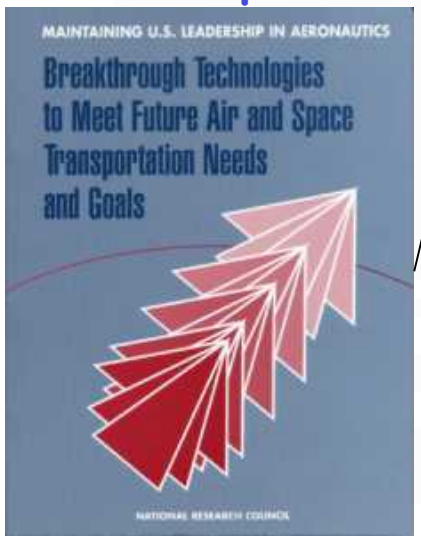


President's Aerospace Commission

Joint Planning Office for National Air Transportation System Transformation *"Economic Growth Through Air Mobility"*

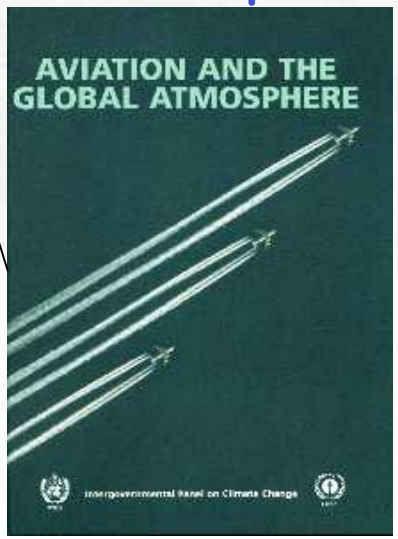
European Aero 2020

NRC Reports



NASA Aero Blueprint

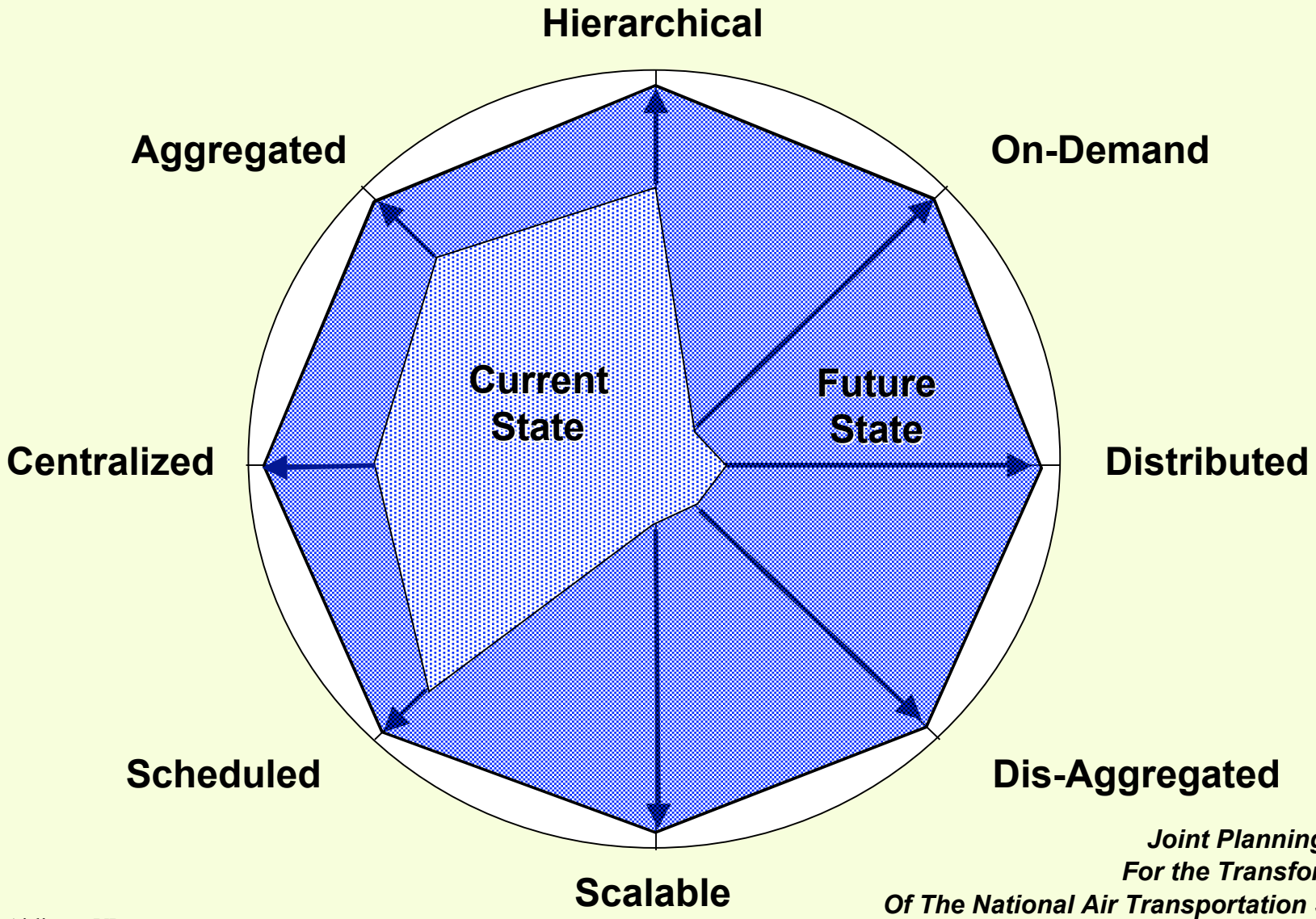
IPCC Report



Transformation Concept Space

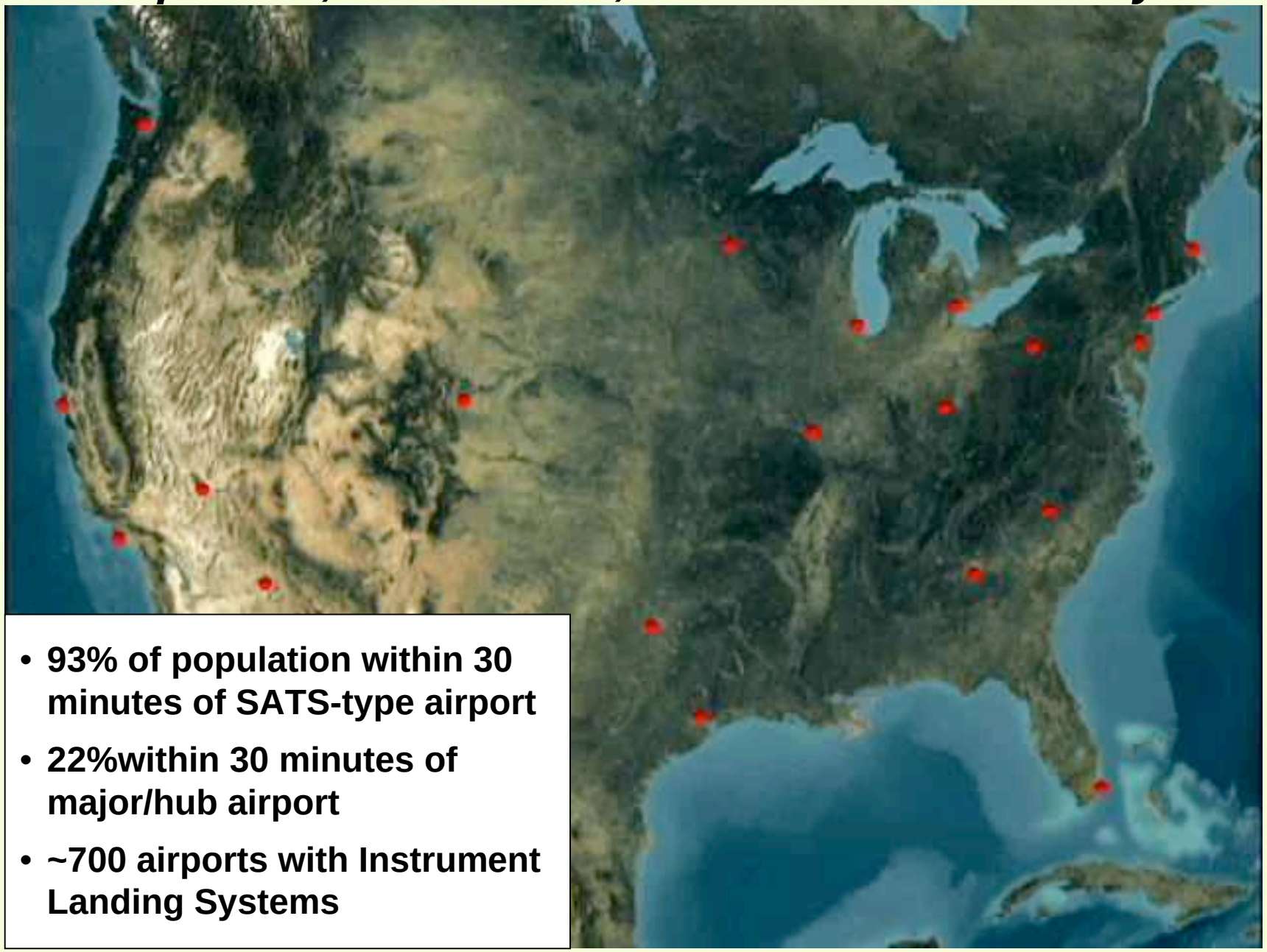
(Notional)

The vision is to expand the concept space along *all* dimensions.



Joint Planning Office
For the Transformation
Of The National Air Transportation System

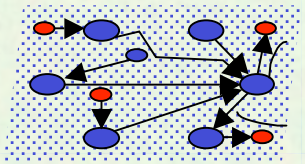
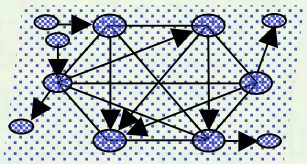
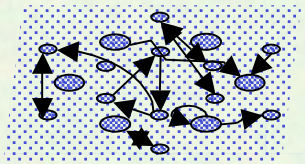
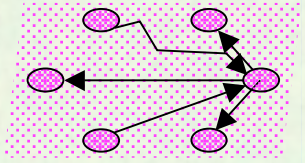
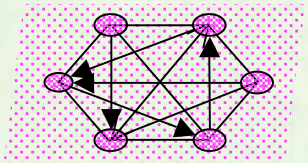
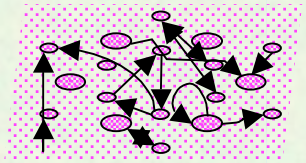
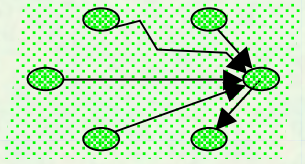
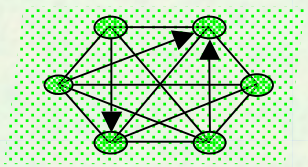
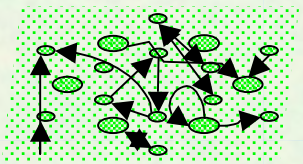
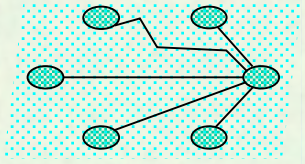
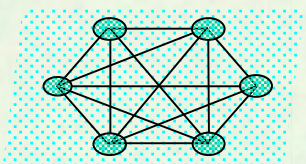
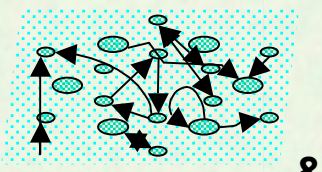
Equitable, On-Demand, Distributed Air Mobility



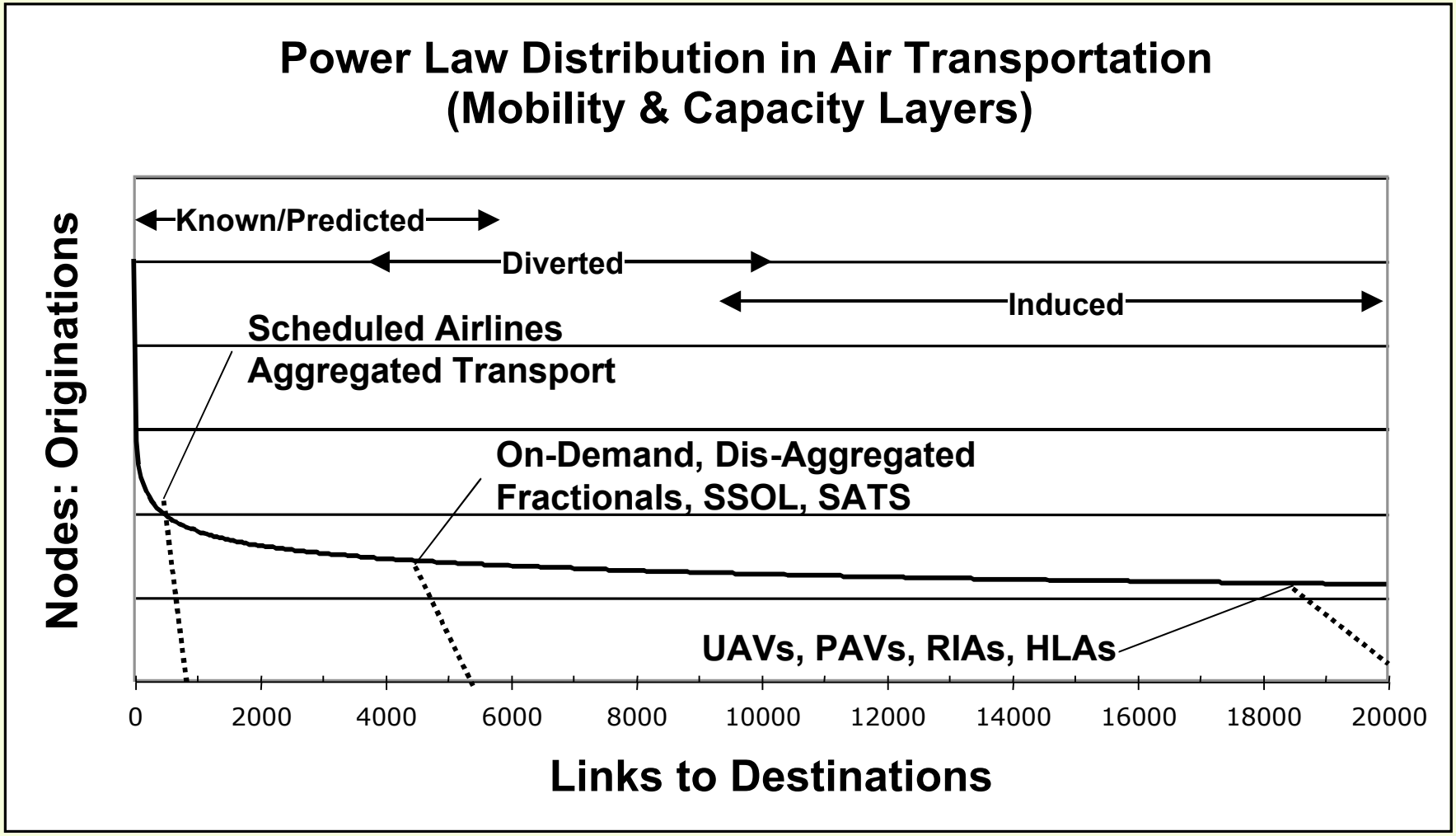
- **93% of population within 30 minutes of SATS-type airport**
- **22%within 30 minutes of major/hub airport**
- **~700 airports with Instrument Landing Systems**

Topologies for Air Transportation Networks

Q: What network characteristics, topologies, and technology strategies would lead to scalable air transportation system behavior?

	A. Hub-and-Spoke Directed, Scheduled, Aggregated	B. Point-to-Point Directed, Scheduled, Aggregated	C. Distributed Undirected, On-Demand, Dis-Aggregated	NAS Layer
Mobility Layer (Passengers/O-Ds)				Communication Navigation Surveillance
Operator Layer (Pilots-Crew/Missions)				A, B, C, D, E, SUA & TFR Architecture
Transport Layer (Aircraft/Routings)				
Capacity Layer (Airports/Routes)				Airspace Services & IFR/VFR Procedures

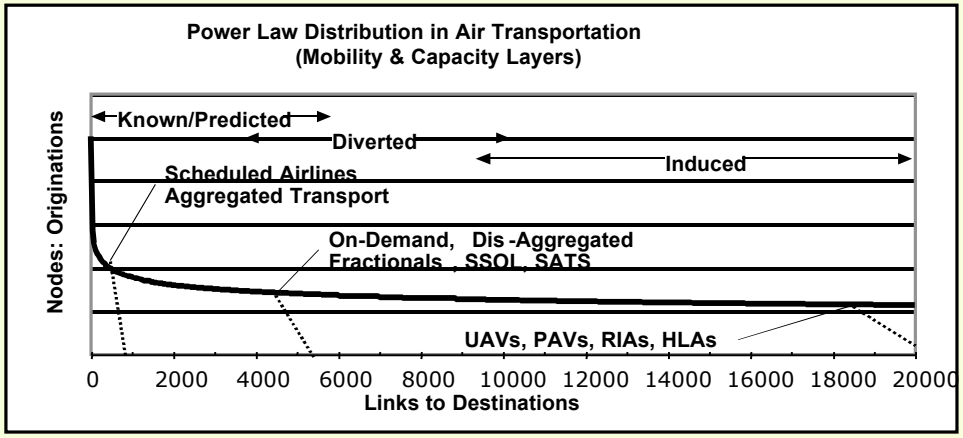
Small World Distribution in Air Transportation

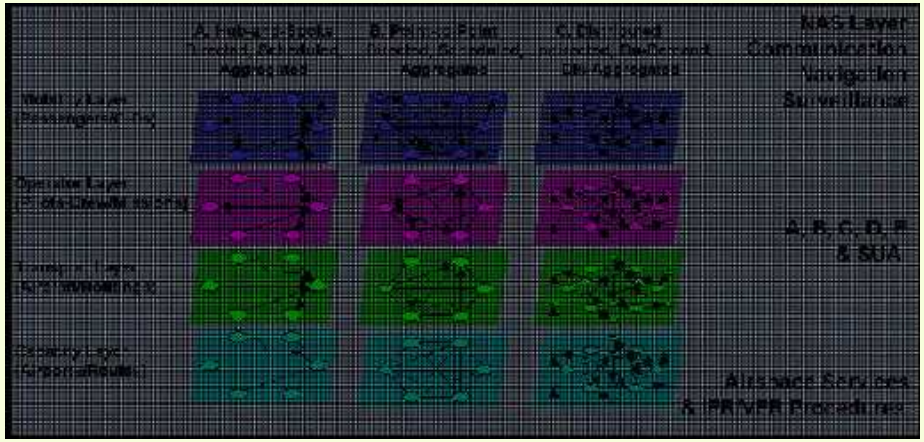


Q: What network characteristics, topologies, and technology strategies would lead to scalable air transportation system behavior?

Topologies for Air Transportation Networks

As framework for primal questions





Primal Questions

1. **What are the comparative mobility metrics (*e.g.,* door-to-door speeds) for networks A, B, and C?**
2. **What are the optimal sizes, costs, performance of aircraft for these networks?**
3. **What are the comparative energy consumptions for optimized operations of these networks?**
4. **What are the comparative noise constraint optimization issues for these networks?**
5. **What are the comparative infrastructure costs at each layer of these networks?**
6. **What are the comparative degrees of resistance to disruptions of these networks?**
7. **What are the comparative degrees of vulnerabilities of these networks?**
8. **What are the percolation behaviors for "events" in these networks?**
9. **What changes occur within the network when one of the layers is fundamentally altered?**
10. **What topology of topologies (system of systems) expands the transformation concept space?**

Reducing the Cost of Speed

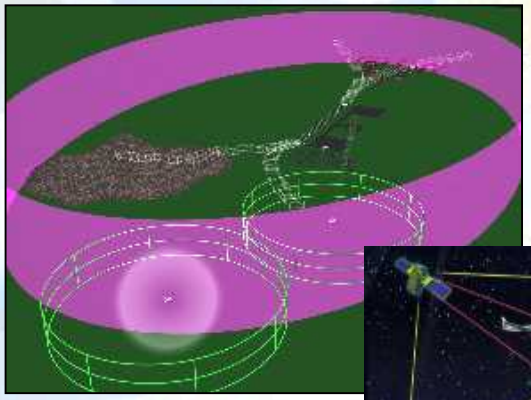
Enabling
New Business Models
For Air Mobility

Honda,
Toyota,
And others…

Innovations Transforming 21st Century General Aviation

Digital Aircraft

- A New Generation of Digital Aircraft
- All-Digital Cockpit Systems (PFD+MFD)
- Digital Flight Controls
- Digital Engine Controls
- Airborne-collaborative Sequencing Software
- Lower Landing Minima Without ILS



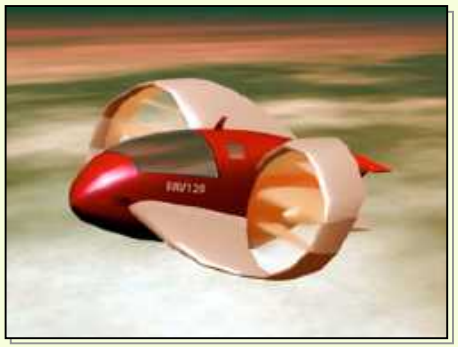
Digital Airspace

- Airborne Internet
- Digital Airport Information Systems
- Digital Airspace Management Systems
- ADS-B-based Separation
- Non-towered Airports Procedures
- Non-radar Operations in IMC

Personal Air Vehicles

Barrier Issues:

- **Advanced vehicle concept design**
  - **Radically "different" configurations**
  - **Strong coupling between aerodynamics, structures, propulsion**
  - **Affordability in terms of transportation mission**
- **Infrastructure independence (CNS and runways)**
- **New propulsion systems for T/W (per dollar)**
- **No noise impact on community and occupants (It's an integrated propulsion / high-lift issue)**
- **Lightweight, long-life structures (It's a materials stiffness/weight issue)**
- **Plus working with a whole new group of Federal Agencies/Organizations and customers**

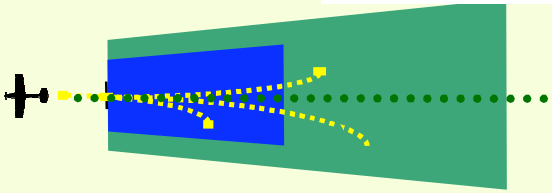


Small Aircraft Transportation System Project

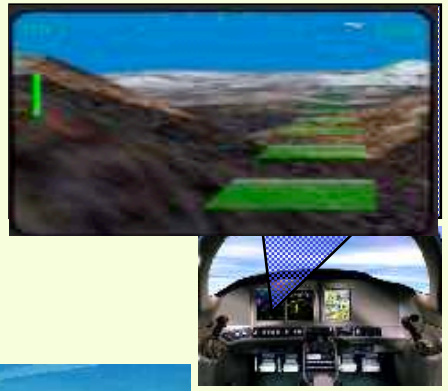
Operating Capabilities for Access to All Communities/

Higher Volume Operations in Non-Radar Airspace and at Non-Towered Airports

Lower Landing Minimums at Minimally Equipped Landing Facilities

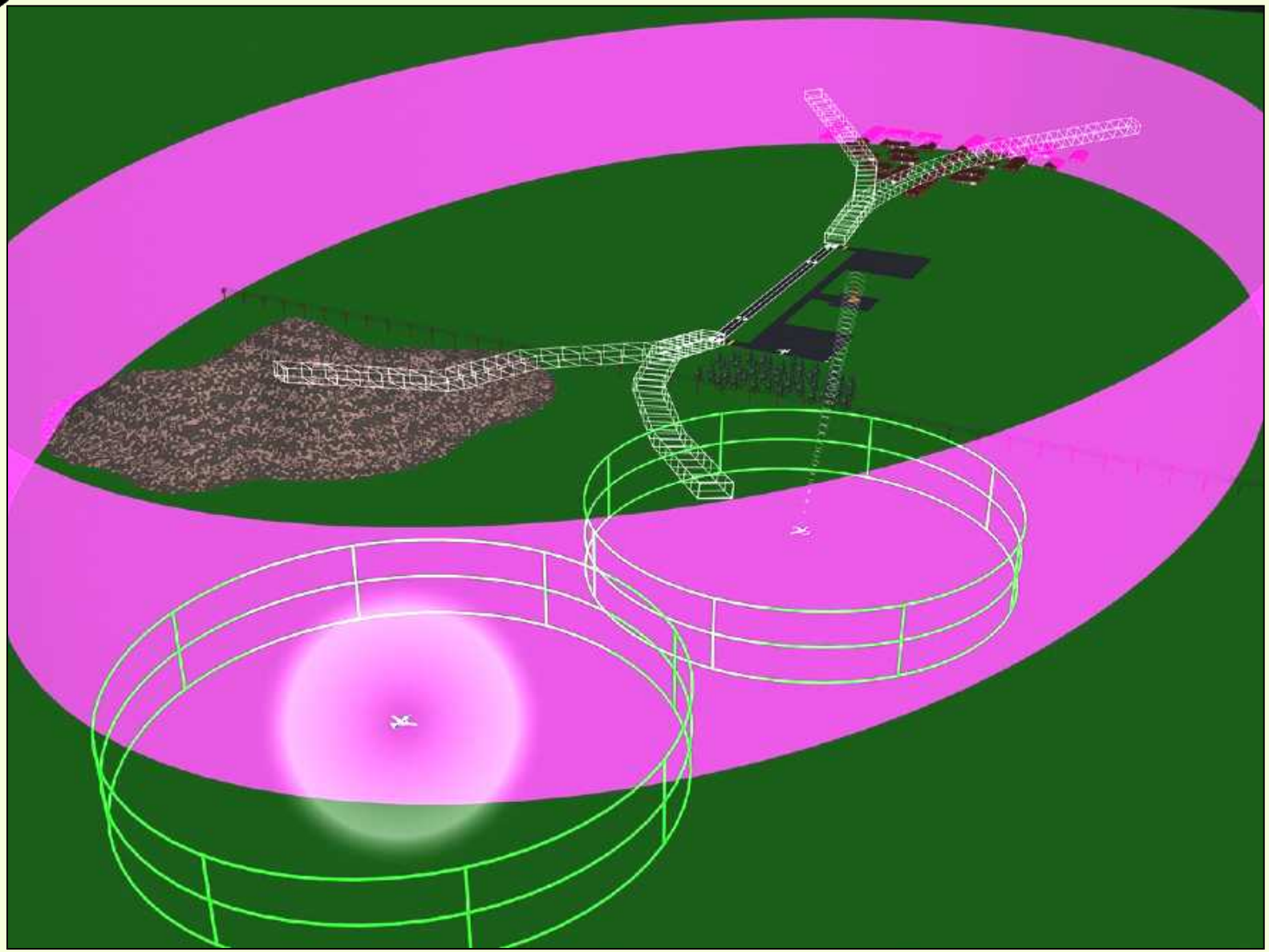


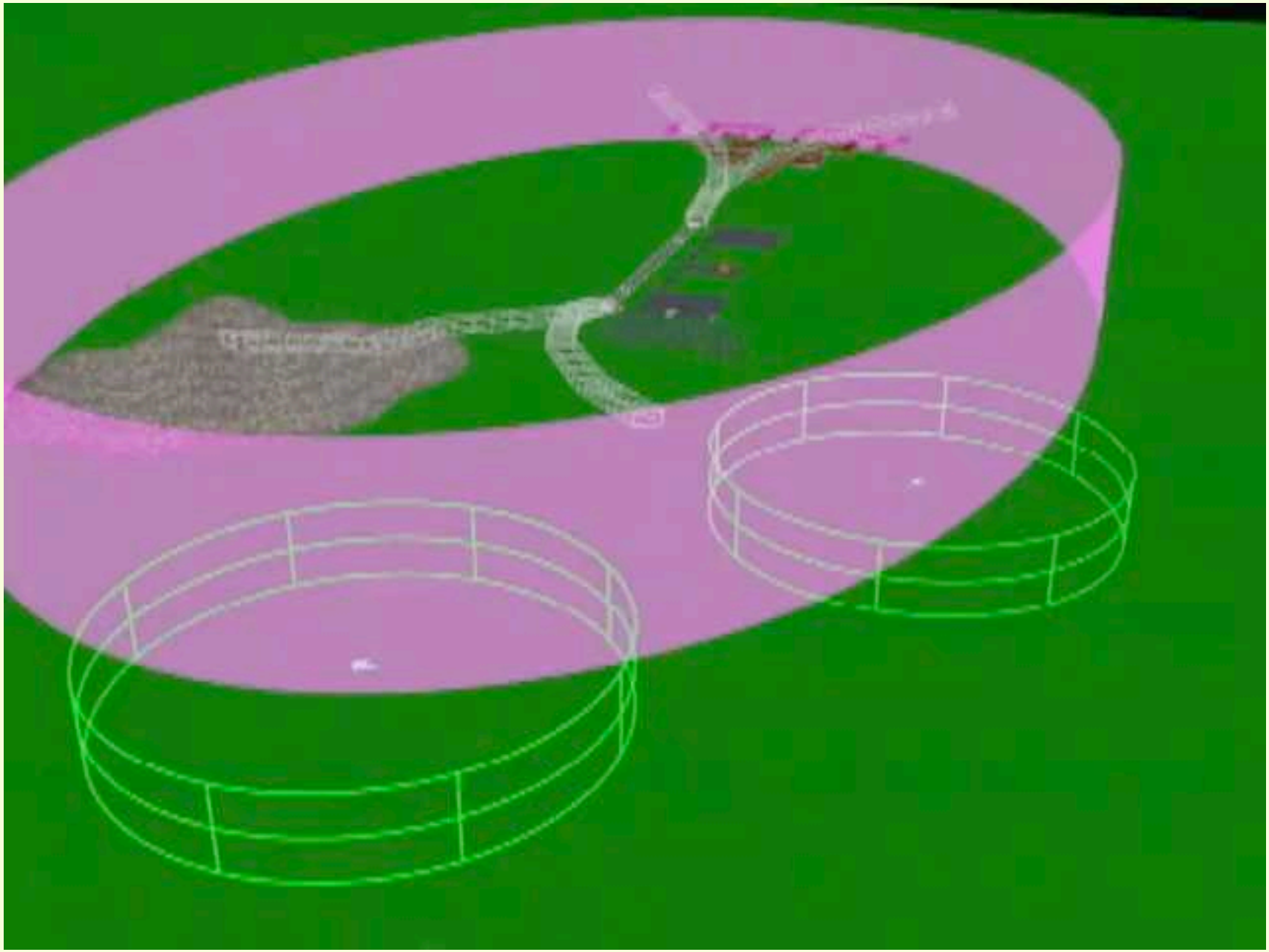
Increase Single-Pilot Crew Safety & Mission Reliability



En Route Procedures & Systems for Integrated Fleet Operations

SATS Operating Capabilities





FAA Roles

Small Community Airports Initiative

- CNS Infrastructure

Safe Flight 21

- Capstone

AVR-SATS Team

- Certification Issues

Flight Standards Services

- Flight Training Technologies
- RNP-based Operations

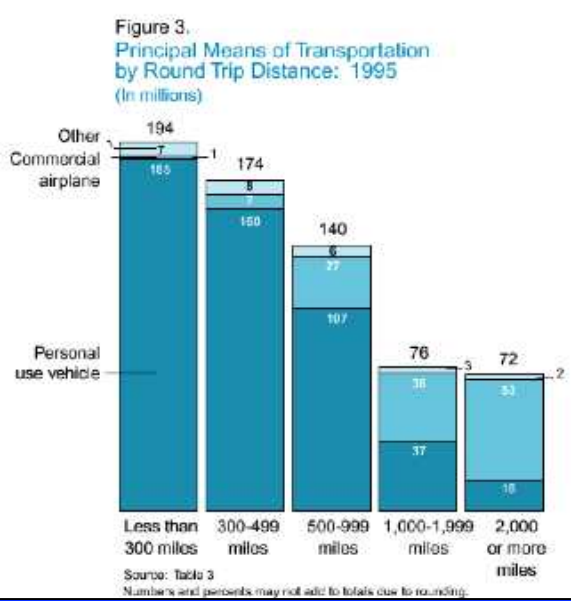
FAA Technical Center:

- Airborne Internet
- Advanced procedures simulations

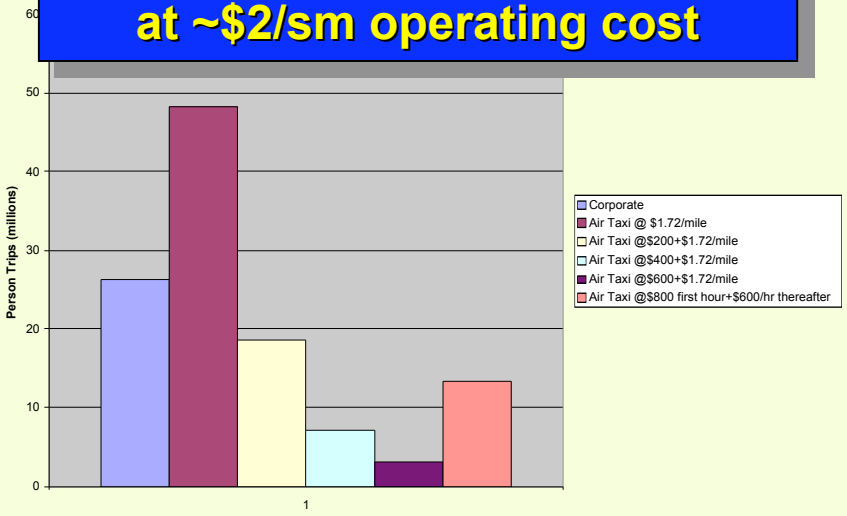
THE COMMON DENOMINATOR IN THESE DEVELOPMENTS IS THE IMPORTANCE OF EFFECTIVE TRAINING IN GENERAL AVIATION

Future Aircraft Market
Diverted Demand and Sensitivity Assessments

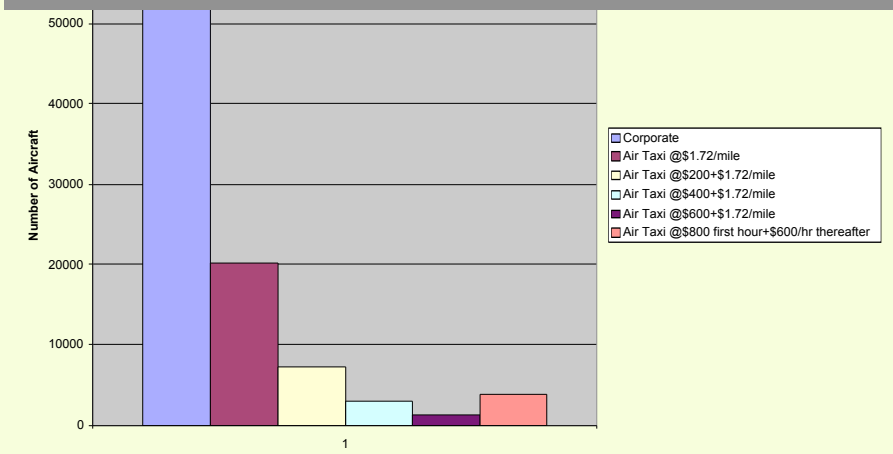
- **Approach - Predict diverted mode choice at National level between automobile, scheduled air, and on-demand air travel based on the value of a traveler's time and the cost of the trip (NASA CR 2002-211927).**
  - **Data Source - 1995 American Travel Survey + 2000 US Census**
  - **Tools - Integrated Air Transportation System Evaluation Tool (IATSET), macro economic model**



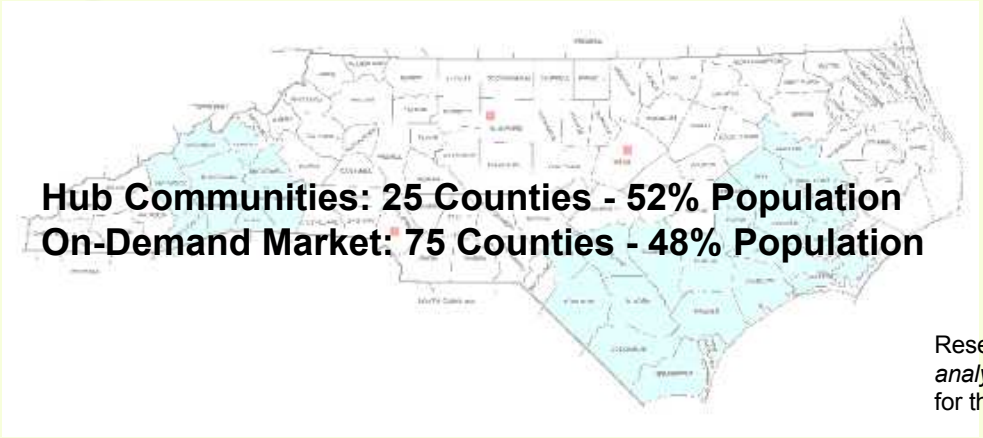
Between 13 and 47 million trips at ~$2/sm operating cost



Between 7,000 and 52,000 aircraft required to serve new markets



North Carolina Market Assessment For Diverted (On-Demand) Business Travel



Assumptions

- **Business Travel (no personal tvl)**
- **98% Accommodation @ ≤ 3 hours**
- **20% ROI held constant**
- **No weather impacts assessed**

Research Triangle Institute (2002). *North Carolina fourth-tier air transportation market analysis*. NCDoA Contract No. A304132: NC DOT Division of Aviation market Analysis for the Small Aircraft Transportation System (SATS) in North Carolina.

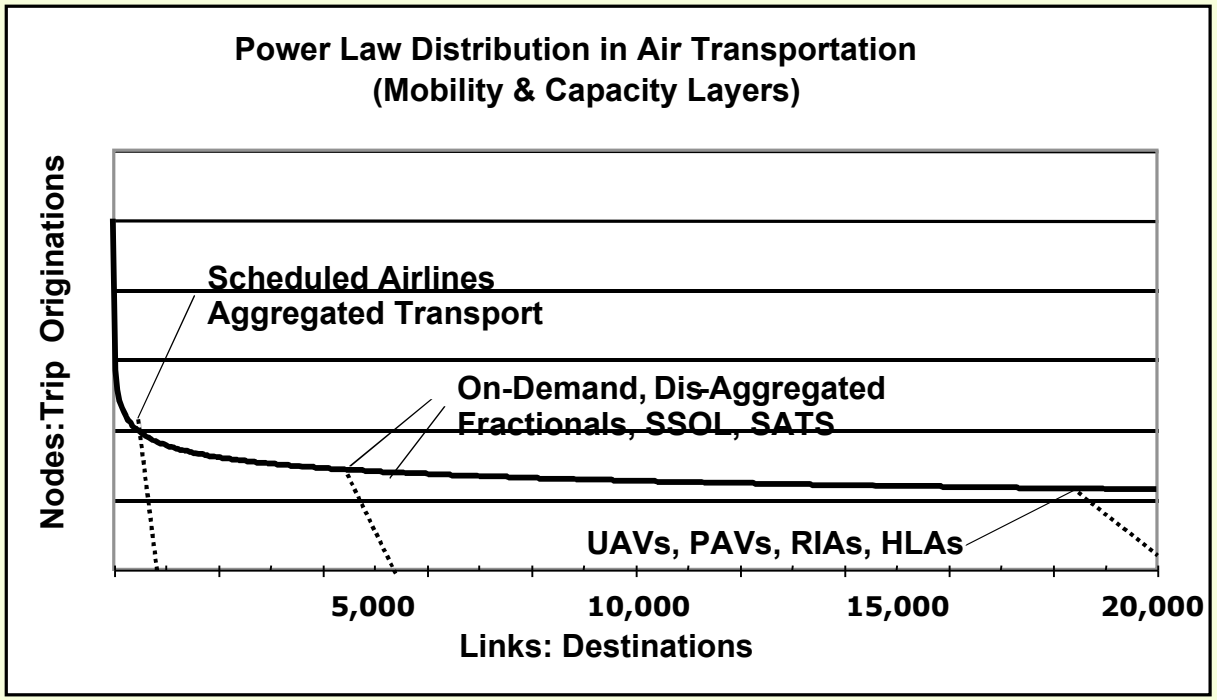
Findings:

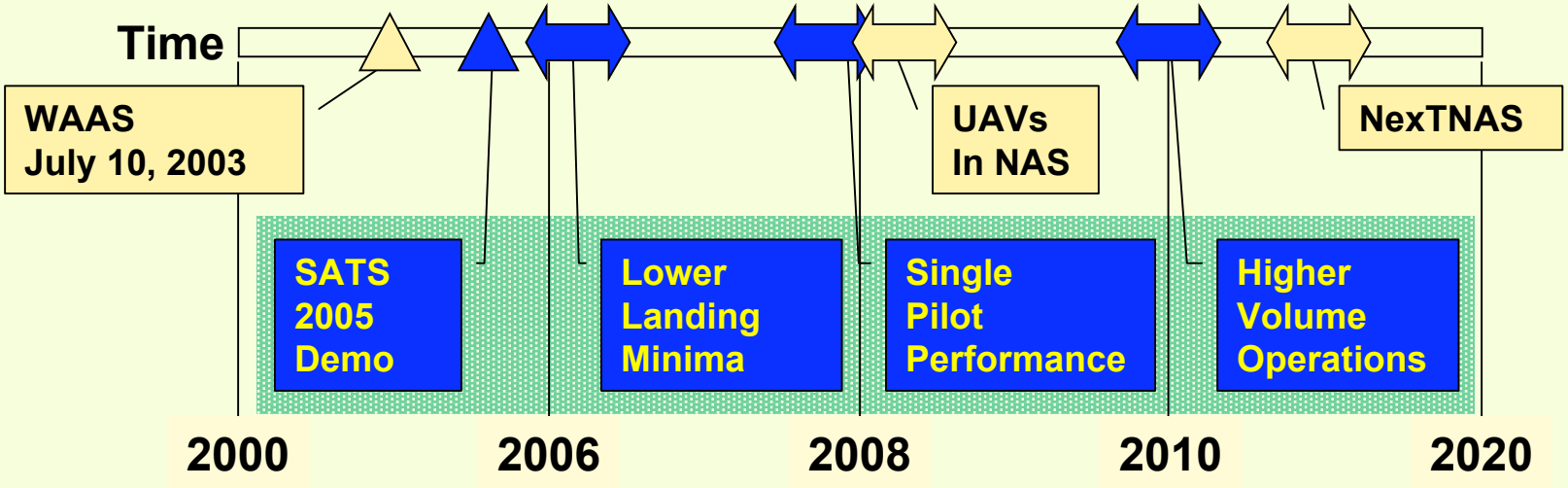
175 fleet of next generation jets required to serve 425 passengers/day demand at $1.85 per passenger-seat mile

- **Demand highest in communities most remote from commercial air service**
- **Air-taxi service best meets needs of surveyed likely business travelers**
- **Increased passenger volume allows higher profit margins and/or lower ticket prices and shorter accommodation intervals**
- **Advanced technology significantly reduces required ticket price**

* Ignores potential passenger demand from “hub communities”, ignores passenger travel originating external to NC, ignores leisure and vacation travel demand, uses simplified dispatch strategy with no “optimization”

Scalable Development of Air Transportation Starts with SATS Operating Capabilities





A Notional Life Cycle For Innovations in Air Mobility

Cumulative Person-Trips

Non-Hydrocarbon Power

What Then??

Intra-Urban

Automated Airspace Self-operated Aircraft

Hired Pilots

Rate of Growth Of Travel

2000 2010 2020 2030 2040 2050

Secret Airline Plan for Simplified Passenger Deplaning

Summary

- Bi-Centennial Context for Transportation System Innovation
- SATS, The Vision:
  - Scalable growth of
    On-demand, Distributed, Dis-aggregated, Air Mobility
    In
    Increasingly Autonomous Aircraft
    In
    Increasingly Demand-Adaptive Airspace
- SATS, The Project:
  - Proof of Concept for
    Airport & Airspace Access
    With Decreasing Traditional Terrestrial
    Infrastructure and Control

- Modern Network Theory Offers A System-Level Topology
  For Air Transportation Network Thinking
- A Technology Roadmap For Air Mobility Offers A Framework for Planning

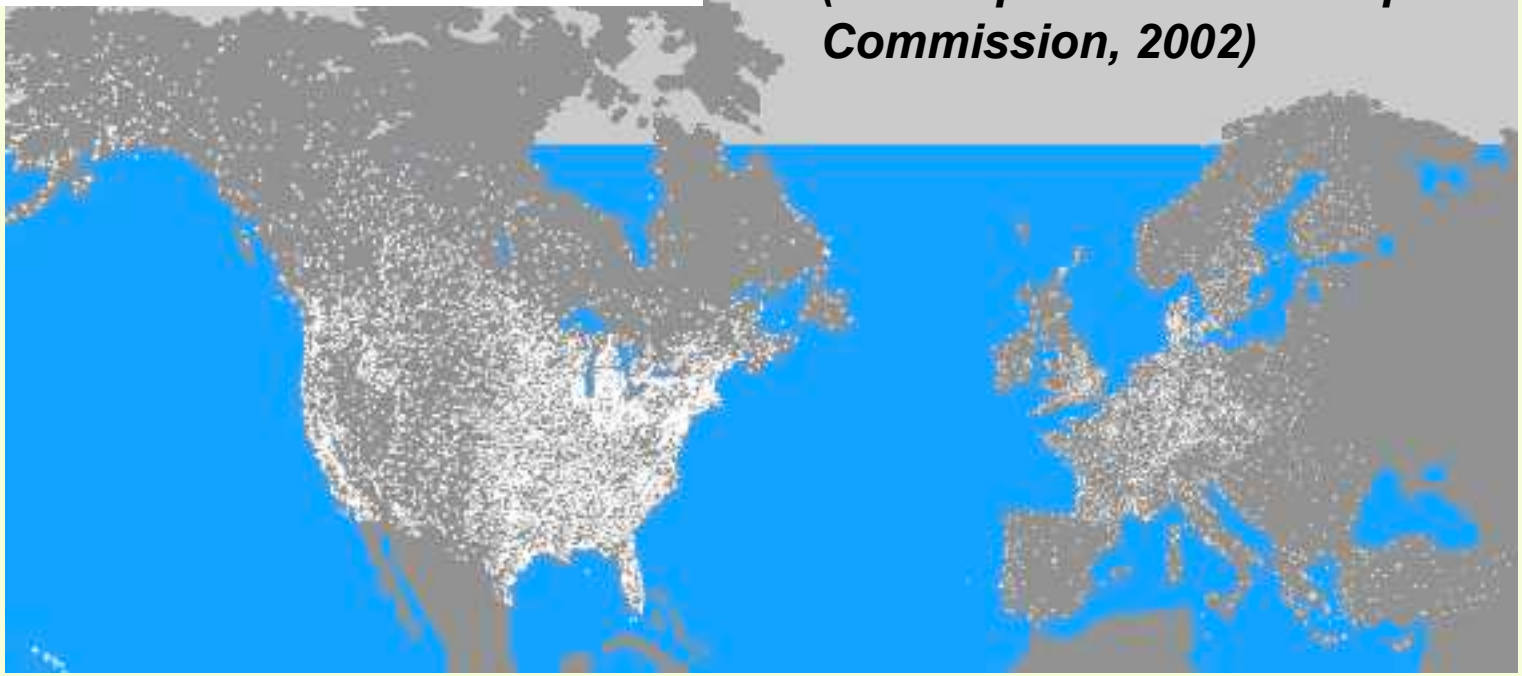
The Risk-Reward Solution Space
Appears Favorable
For Air Transportation System Innovations

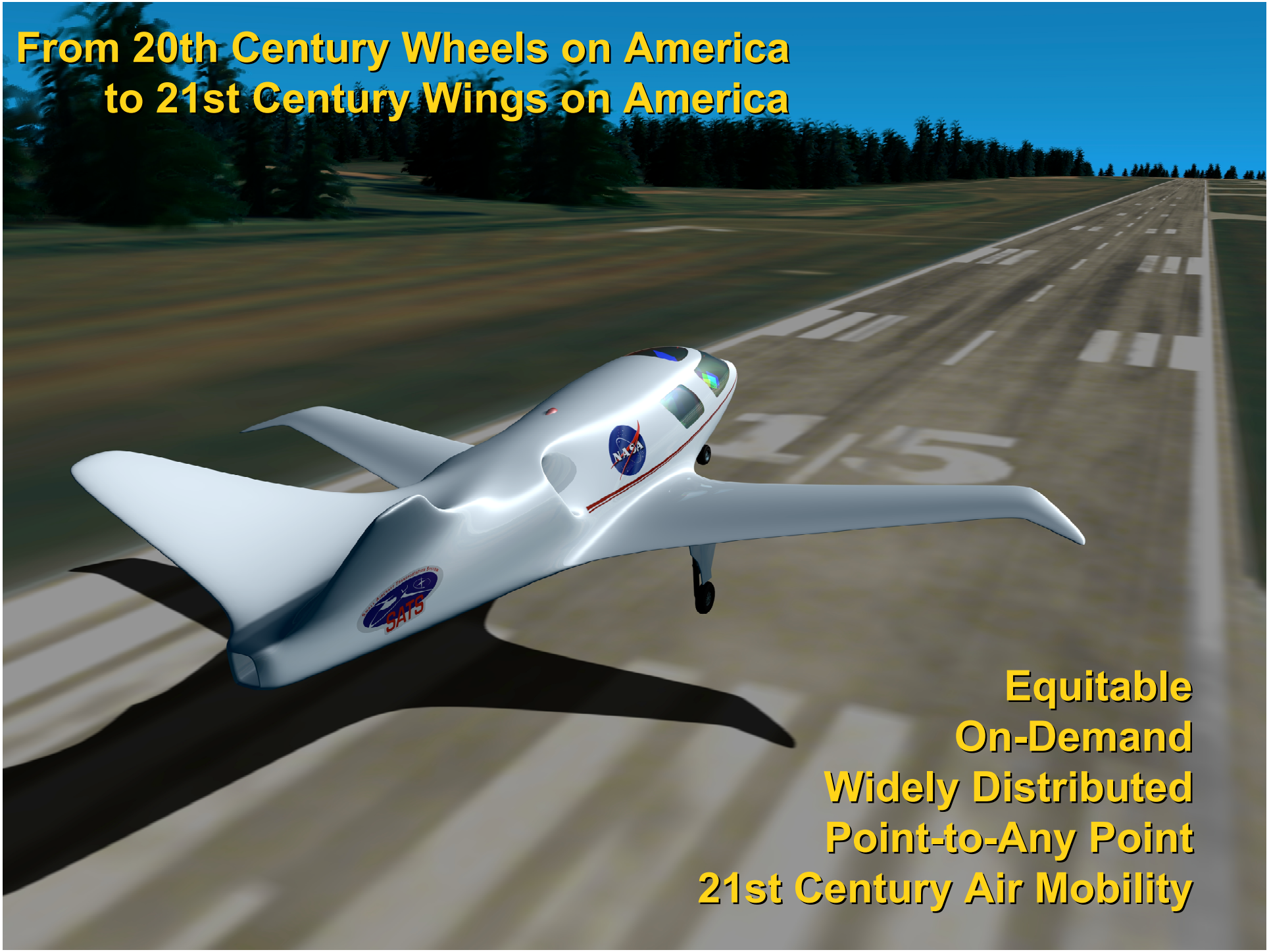
Epilogue …
Or Prologue?

From the sands of Kill Devil Hill

To
"Anywhere, Anytime, Anyone, Anyplace"

(The Report of the Aerospace Commission, 2002)




From 20th Century Wheels on America
to 21st Century Wings on America
NASA
SATS
Equitable
On-Demand
Widely Distributed
Point-to-Any Point
21st Century Air Mobility